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The design of innovative CIP machine for heat exchangers

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Abstract

The heat exchanger is part of a device which is designed to effectively transfer heat from one environment to another. Exchangers are widely used in heating, cooling, air conditioning, power stations, chemical factories, petrochemical factories, oil refineries using them in the processing of natural gas and also used in sewage treatment. The heat exchanger needs as well as other technical equipment regular servicing and maintenance. The cleaning of exchanger, which is soldered or separable (without the need for disassembly) constructed, provides portable CIP machines. The paper deals with possibilities of design the CIP machines which take account of all factors for potential using in the cleaning process. There is described development of innovative CIP machine which use the special polypropylene pneumatic pump to exchange special cleaning medium which release impurities and sediments through chemical processes in the distribution pipelines.

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Keywords: design, CIP machine, heat exchanger

1. Introduction

The exchangers are widely used for heating, cooling, conditioning, electric power station, in chemical factories and petrochemical factories, natural gas processing and waste water treatment. Heat exchangers can be classified according to the method of using (heating, cooling, boilers, capacitors etc.), depending on the arrangement (heat exchange between two or more fluids etc.), according to the type of the heat exchange (no change or to a change in the physical state), or according to the contacts a the fluids (heat mixing - mixing together the media, regeneration heat exchangers with a single heat transfer surface area, which alternately is washed by warm and cold flow, taking advantage of the accumulated heat, a finally continuously recuperative heat exchangers in which the flows are separated by a wall - heat transfer surface area). Classification of heat exchangers is not clearly defined. For heating homes and workplaces are mostly used recuperative heat exchangers, although the principle of regenerative heat exchanger can be very significant.

The heat exchanger is part of a device which is designed to effectively transfer heat from one environment to another. The most important parameter of each heat exchanger is the temperature power output which is different with many factors, mainly the temperature difference between the heating a heated side exchanger (called temperature differential of heat exchanger, or the mean temperature difference exchanger), the flow in the heating and the heated side of the exchanger and the type or nature of the liquid. It is not possible therefore clearly indicate the performance of heat exchangers without specifying the operating conditions for which they work. In general, the higher the temperature difference between the heating a heated side the higher is the flow on either side of the exchanger, the higher the power output of the exchanger. The heat exchangers are always designed for the specific application and operating conditions.

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The heat exchanger is device for exchange of heat between different circuit and mediums. For the best heat power the heat exchanger needs as well as other technical equipment regular servicing and maintenance. The cleaning of exchanger, which is soldered or separable (without the need for disassembly) constructed, provides portable CIP (Clean in Place) machines.

2. Principle of chemical cleaning by CIP machines

During the using there may be fouled various sediments in the heat exchangers, according to the type of the flowing medium. The most common reason is bad water quality combined with an unsuitable temperature regime. The sediments, their development and their elimination are different according to application. In the preparation of hot water there are typical of lime and lime - magnesium sediments. Their disposal is relatively easy at temperatures as low by using a wide range of acids.

In circulation system with treated water there is low residual calcium hardness, and creates this increasingly ferrous sediment, oxides, often combined with lime components in the form of iron carbonates. The more is ferrous proportion in the sediments the more is removing complicated. In this case there is necessary to use a significantly more aggressive acid, typically in a mixture. Biological sediment such as grease, oil and oil products, paints, etc., is possible to relatively easily dispose by strong liquors with an alkalinity of about pH 10 - 11. In chemical processes are formed very difficult deposits, often in the form of the complex and there is usually necessary cleaning compositions to test.

Soldering plate heat exchangers, with its compactness cannot be cleaned mechanically and therefore a fall in power or increase in pressure loss must be chemical cleaned. If influence of sedimentation is totally blocking each channels or the whole exchanger, the heat exchanger will not possible to clean and the exchanger must be replaced with a new one. Clean plate heat exchangers in the place of installation is possible with CIP machines.

Cleaning in Place (CIP), a method used for the interior surfaces of closed systems, such as pipes, vessels, process equipment, and filters. A chemical fluid is circulated through the unit, without the need for disassembly. The chemicals dissolve or loosen deposits from process equipment and piping, giving uniform removal and lower overall operating costs. The principle of cleaning process by CIP machine is on Fig. 1. For the cleaning process at first there is needed to turn off relevant pumps and empty the heat exchanger. In the step two there is connected a CIP machine to lower and upper extra connections. Pump the cleaning solution through the heat exchanger from the lower connection. The flow is reversed every 30 minutes with application a flow rate of 1.5 times the nominal flow if it is possible. Monitoring the pH and/or pressure drop signalize when is possible to finish cleaning process. Cleaning is finished when the pH has been constant for 30 minutes, and/or the pressure drop has returned to its initial value. In the step three the CIP machine is stopped and with exchanger is drained. In the next is heat exchanger flush with water until the water is neutral (pH7). After there is CIP machine stopped and heat exchanger is drained. In the final there are closed the CIP valves and opened the main valves.

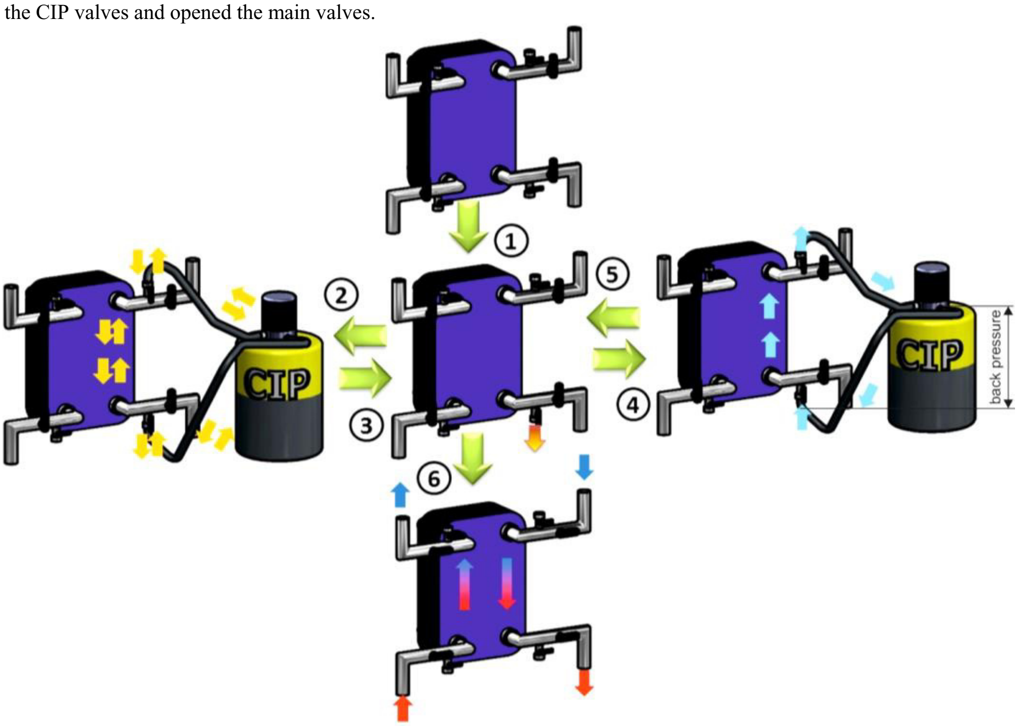

Fig. 1. Process of cleaning by CIP machine

The steel can be passivized after cleaning by circulating 2% phosphoric acid at 50℃ (122℉) for 4-6 hours. This will reduce the corrosion rate due to the precipitation of corrosion product on the metal surface, and inhibit further corrosion in water or in air.

3. The design of innovative CIP machine

The design of innovative machine must in principle comply with the necessary requirements for its construction, which are dependent on its function. The main function of the CIP is a closed circuit to ensure the flow of cleaning medium, which circulates between the closed filtration tank and heat exchanger. Cleaning medium must be heated to the desired temperature a 50 ° C (122 F). Here it is necessary to determine the performance of the heating element, depending on the volume of the vessel, the temperature difference and the time required to heat the media. To media circulation was secured, it must be cleaning unit equipped with a pump. For monitoring and control it is equipped with a control and monitoring unit. The tank and the necessary accessories must be mounted on a mobile frame to ensure the mobility function.

3.1. On pump selection

In the design of CIP machine, we started from the requirement to apply the pressure air operated diaphragm pumps (Fig. 2), which can work in various fields of industry. Most often, however, air operated diaphragm pumps are used where it is necessary to transport problematic media and where the other types of pumps fail.

Elements of air operated diaphragm pumps are made from stainless steel, cast iron, aluminum, polypropylene, polyvinyl fluoride (PVDF) and titanium. Diaphragm and part of valves are with nitrile rubber (NBR), neoprene (CR), Nordel (EPDM), Hytrel (TPEE), (FPM) or Teflon (PTFE). Combine appropriate Pump materials can be safely pumped floodplains, acids, bases, solvents, adhesives, alkaline fluids, resins and the like.

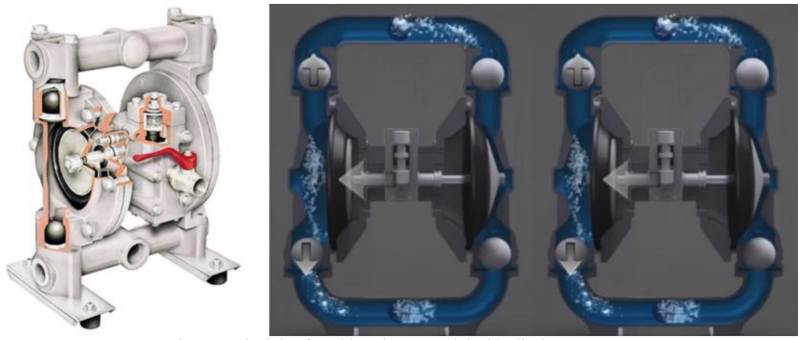

Fig. 2. Principle of working air-powered double diaphragm pump

The air is ported through the air valve piston into the center block, where two directional ports direct the air to the left or right side of the pump. The pump has two liquid chambers, two air chambers and two diaphragms. In each pair of chambers, the liquid and air chambers are separated by a flexible diaphragm. When in the air chamber, the air pressure is applied on the back side of one diaphragm forcing the product out of the liquid chamber into the discharge manifold. As the two diaphragms are connected by a rod, or shaft, the other diaphragm is pulled towards the center of the pump. This causes a suction stroke on the other side. Ball valves open and close alternately to fill chambers, and block back-flow. At the end of the shaft stroke, the air mechanism (air valve piston) automatically shifts the air pressure to (opposite side) reverse the action of the pump, simply put a 1:1 ratio reciprocating pump.

To determine compressed air requirements and proper size for an air-powered double diaphragm pump, two elements of information are required:

- required flow rat (l/m)
- total dynamic head (back pressure)

To we determined if a particular pump's performance meets our requirements, first we need to determine the desired supply air pressure. The relation between the discharge pressure head and discharge volume at various air pressures is plotted on the performance curve with solid line (Fig.3.). Next, we need to determine if the desired discharge volume and discharge pressure head fall under the selected supply air pressure curve.

And then, we need determined if the desired discharge volume and discharge pressure head fall under the selected supply air pressure curve. If so, the pump is adequate for our needs; if not, a larger capacity pump and/or higher supply pressure is required.

The dashed lines on the performance curve indicate air consumption at the desired discharge pressure head and discharge volume. Note that consumption is not affected by air supply pressure. All test data in this graph are at normal temperature (70°F) using fresh water and 1 ft. flooded suction. Discharge volume and discharge head may vary according to the characteristics (viscosity, specific gravity, etc.) of the liquid.

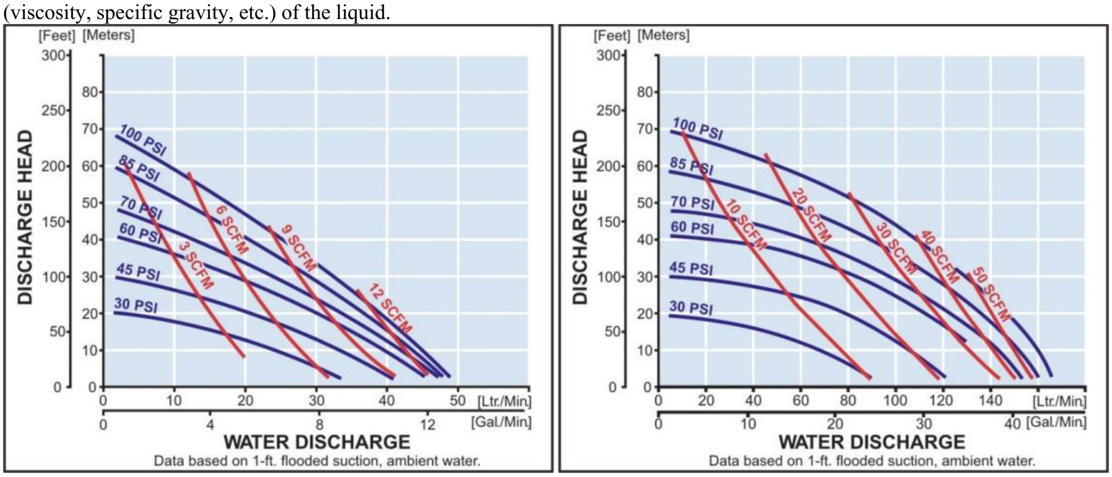

Fig. 3. Performance curves of designed pumps – NDP 15 (left picture), NDP 25 (right picture)

3.2. Design of distribution scheme

The innovative devices for cleaning heat exchangers is typical with media transport in multiple circuits. Distributor composed a group of hoses, fittings and valves has been designed in order to ensure two basic areas:

1. The circuit providing supply the cleaning medium to the heat exchanger
2. The circuit providing a reverse flow of cleaning medium through the exchanger

Meaning of distributor is mainly in the possibility to turn the flow of medium without changing the connection to the heat exchanger, for reverse the flow of medium. The distributor works in principle on the regulation of the flow control valve by means of ball valves 1 to 4. By closing of control valves 2 and 3 there is medium flow directed from tank trough pump to left connection on heat exchanger. Through heat exchanger is directed cleaning medium which releases sediment by chemical processes. Medium with sediment flow through right connection to heat exchanger and there is directed to input tank where is filtered by two filters. For reverse flow we have to open valves 1 and 4 and to close valves 2 and 3. Then is flow directed from tank trough pump to right connection on heat exchanger. From exchanger is medium directed to tank. For air pump the CIP machine have separate air distribution system. Principle and scheme of designed distributor is on Fig. 4.

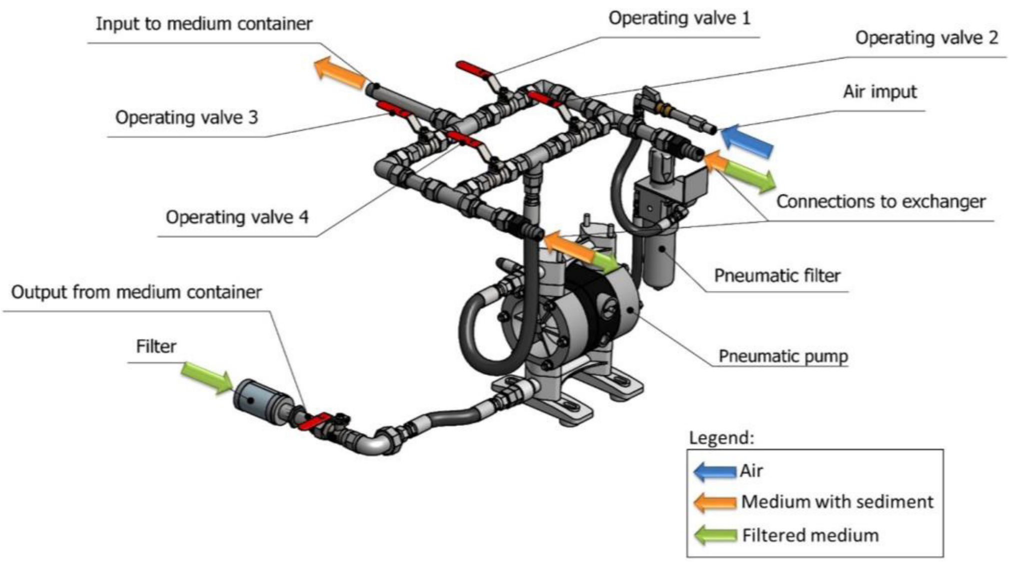

Fig. 4. Distribution scheme of designed distributor

Media distribution system is designed to allow a third circuit for removing the medium after the cleaning process. After disconnecting the heat exchanger and closing valves 1 and 3 will be discharged through the medium of connection to the exchanger to waste.

3.3. The heater power calculation

Suggest ways of heating a container with cleaning medium is subject to electric heating, which provides high efficiency heating η = 0.98, and the possibility of universal connection in a specified location of cleaning. There it is necessary to determine the dependence of the performance of the heating element, depending on the volume of the medium and the temperature difference (T1-T2) between the inlet and outlet temperatures of the cleaning medium. We will build on the values of the heat capacity of water, which represents the value of:

$$c = 4186\left[\frac{J}{kg.K}\right] \quad (1)$$

and expresses the needed of heat in joules, the body should be added to the temperature increase of 1 ° C (degree Celsius). When a unit conversion derivation of specific heat capacity of the J Wh posed

$$J = \frac{1}{3600}\left[W.h\right] \quad (2)$$

then the specific heat capacity is expressed as follows:

$$c_{Wh} = \frac{4186}{3600}\left[\frac{W.h}{kg.K}\right] \quad (3)$$

Energy is needed to heat medium from an initial temperature to the required temperature t2 t1 of mass m, which is dependent on the volume V and the density ρ calculated:

$$E = m.c_{Wh}(t_1 - t_2) = \rho.Vc_{Wh}(t_1 - t_2) \quad (4)$$

Required input power of the electric heater can be determined based on the efficiency of heating and the time needed to heat τ.

$$P = \frac{1}{\eta}\frac{E}{\tau}\left[W\right] \quad (5)$$

Based on the stated we can determine the necessary power of the heater for tanks of different volumes required and the time required for its heating up. The values of power and time needed to heat media within the volume 100 liters to 500 liters container are represented in Fig. 5.

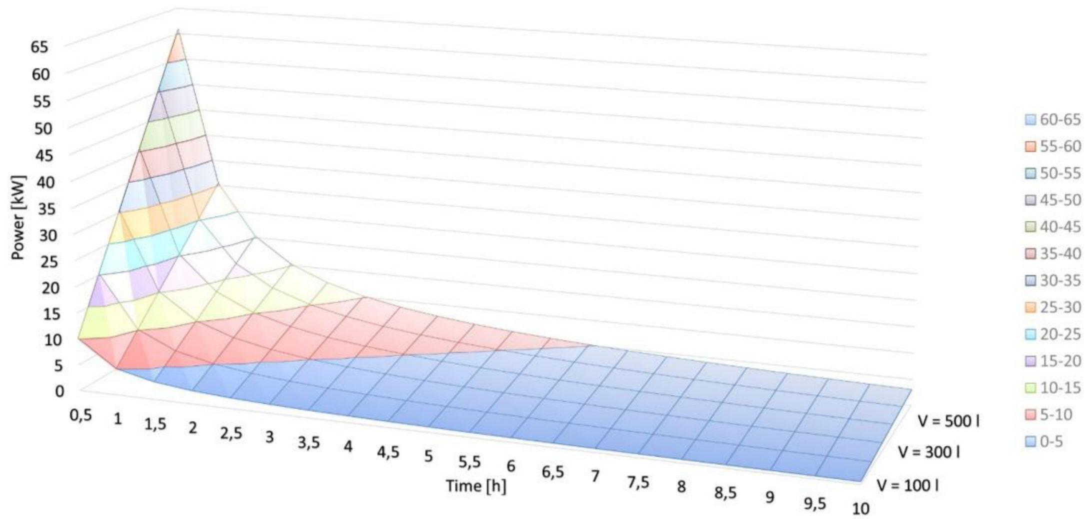

Fig. 5. Determination of power heat

3.4. Constructional design and technical specification

In the design of the device has been used 3D CAD system that allows design optimization due to boundary conditions. The overall concept of layout components of the device has been designed so that the overall dimensions of the device are as small as possible. Frame construction as easy as possible but also strengthens. Take into account all the conditions for assembling and interchangeability of the individual parts and the most efficient maintenance of the equipment during operation.

Welded frame construction is made of square tube stainless steel AISI 304. On the frame construction was attached double jacket tank with heat insulation for keeping required temperature of the cleaning media. In the tank is attached filter coarse particles that captures sediment filtration in the first part. On the bottom of tank is placed the fine particle filter, which prevents the impurities to get into the circulation. The container is closed with a lid and clipped quick-clamps. Container cleaning process is simple and allows to get the maintenance to each part of the container after its release. The distributor is attached at the top, so that the valve control, connection setup and circulation to be the best. The container is provided with the exhaust of air so as not to pressurize bottom of tank. Part of the distributor system also includes control and management with flow control elements, pressure and temperature. The device is complemented by a series of regulatory connecting members for connection to different sizes exchangers. The device was designed in two alternatives with the technical specifications set out in Table 1. The final concept of the CIP machine is on Fig. 6.

Table 1. Technical specification of designed machine

	CIP 200	CIP 400
CONTAINER VOLUME	200 l	400 l
CIRCULATION PUMP	Air-Powered Double Diaphragm pump	Air-Powered Double Diaphragm pump
PUMP MATERIAL	Polypropylene	Polypropylene
PUMP CONNECTION SIZE	DIN 11851 DN 15	DIN 11851 DN 25
AIR SUPPLY PRESSURE	1,4 - 7 BAR (20—100 PSI)	1,4 - 7 BAR (20—100 PSI)
DISCHARGE VOLUME PER CYCLE	128 cc (0,034 US gallons)	833 cc (0,22 US gallons)
MATERIAL FOR WETTED PARTS	Stainless steel AISI 304/316	Stainless steel AISI 304/316
HEATIN POWER	6 kW	12 kW
HEATING TIME	2 hour	3 hour
MAX OPERATING TEMPERATURE	75 °C	75 °C
MACHINE WEIGHT	115 kg	205 kg
MACHINE SIZE	1091x745x1000 mm	1400x1005xx1250 mm

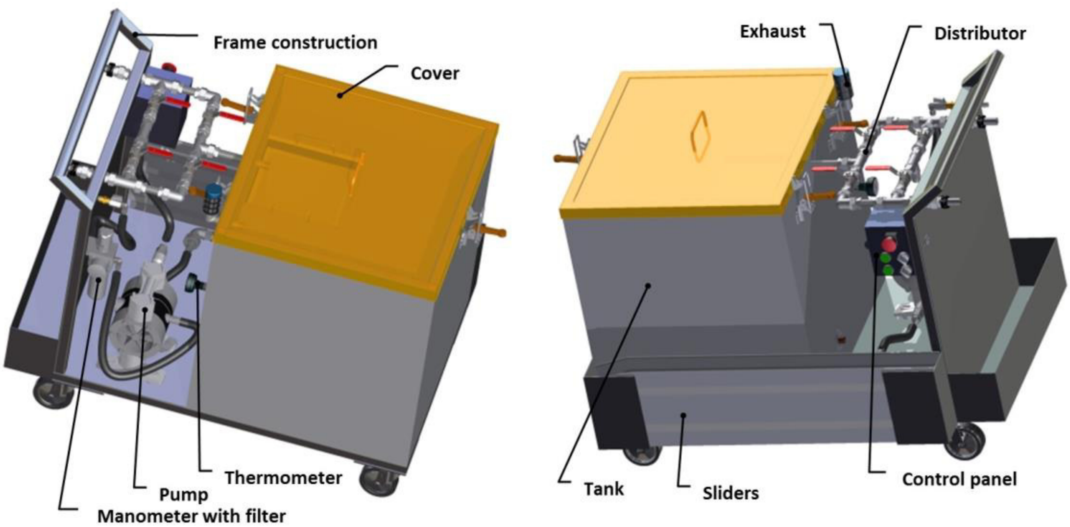

Fig. 6. Visualisation of concept designed CIP machine

4. Conclusion

Innovation is the basis for the successful progress of the company. To know the fundamentals principles and translate them into a functional result is a sense of progress. The design of innovative devices for cleaning heat exchangers is part of the innovation voucher project, which is realized within the University of Presov and businesses. Its aim was analyzed the possibilities of design of innovative devices for cleaning heat exchangers that would meet the requirements for functionality, mobility, efficiency and economic efficiency. In this project, project workers of Presov University to design the device. Its production and further placing on the market will be the subject of further cooperation.

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